Capture Zone Evaluation And Path Forward

GM-38 Area Groundwater Treatment Plant

Naval Weapons Industrial Reserve Plant
Bethpage, New York

Naval Facilities Engineering Command
Mid-Atlantic

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CAPTURE ZONE EVALUATION AND PATH FORWARD

GM-38 AREA GROUNDWATER TREATMENT PLANT

NAVAL WEAPONS INDUSTRIAL RESERVE PLANT
BETHPAGE, NEW YORK

Submitted to:
Naval Facilities Engineering Command Mid-Atlantic
9742 Maryland Avenue
Norfolk, Virginia 23511-3095

Submitted by:
Tetra Tech, Inc.
234 Mall Boulevard Suite 260
King of Prussia, Pennsylvania 19406

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PREPARED UNDER THE
DIRECTION OF:

DAVID BRAYACK, P.E.
PROJECT MANAGER
TETRA TECH, INC.
NORFOLK, VIRGINIA

APPROVED FOR SUBMISSION BY:

JOHN TREPANOWSKI, P.E.
PROGRAM MANAGER
TETRA TECH, INC.
KING OF PRUSSIA, PENNSYLVANIA

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ACRONYMS AND ABREVIATIONS

bgs	below ground surface
BCP	Bethpage Community Park
BWD	Bethpage Water District
1,2-DCE	cis-1,2-dichloroethene
CLEAN	Comprehensive Long-Term Environmental Action Navy
CTO	contract task order
gpm	gallon per minute
GWTP	groundwater treatment plant
MCL	Maximum Contaminant Level
MSL	mean sea level
MW	monitoring well
NAVFAC	Naval Facilities Engineering Command
ND	Not Detected
NG	Northrop Grumman
NWIRP	Naval Weapons Industrial Reserve Plant
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
OU	Operable Unit
OW	Outpost Well
PCE	tetrachloroethene
PWS	public water supply
ROD	Record of Decision
RW	recovery well
SFWD	South Farmingdale Water District
TCE	trichloroethene
TCL	Target Compound List
TVOC	total volatile organic compound
Tetra Tech	Tetra Tech, Inc.
TOC	top of casing
TSS	total suspended solids
µg/L	micrograms per liter
USGS	United States Geological Survey
VOC	volatile organic compound
ZOC	zone of contribution

1.0 INTRODUCTION

This Capture Zone Evaluation and Path Forward Report for the GM-38 Area Groundwater Extraction, Treatment and Discharge System (GM-38 Groundwater Treatment Plant [GWTP]) was prepared by Tetra Tech, Inc. (Tetra Tech) for the Naval Facilities and Engineering Command (NAVFAC) under the Comprehensive Long-term Environmental Action Navy (CLEAN) IV Contact No. N62470-08-D-1001, Contract Task Order (CTO) WE06. This report provides an evaluation of the current effectiveness of the GM-38 GWTP in treating the area of elevated volatile organic compounds (VOCs) in groundwater near monitoring wells GM-38D and -38D2 (GM-38 Area Groundwater), as identified in the Navy's 2003 Operable Unit 2 (OU2) Record of Decision (ROD), and provides recommendations for path forward options for this facility at the former Naval Weapons Industrial Reserve Plant (NWIRP) Bethpage, New York (Figure 1-1 and 1-2).

1.1 OBJECTIVE AND PURPOSE

The GM-38 GWTP (Figure 1-3) was constructed as part of the Off-Site Groundwater Remedy identified in the 2003 OU2 ROD for the NWIRP Bethpage (NAVFAC, 2003). Also shown on Figure 1-3 are groundwater recovery wells, monitoring wells, and an injection well. The objective of the GM-38 GWTP remedy is to provide additional protection of human health by remediating an isolated hot spot of chlorinated VOCs in groundwater. The hot spot area is defined in the OU2 ROD as groundwater containing greater than 1 part per million (1,000 micrograms per liter [µg/L]) of VOCs. The GM-38 GWTP remedy is enhancing the long-term natural process of aquifer restoration by removing a significant mass of VOCs. Based on groundwater investigations conducted in the early 2000's that defined the plume characteristics, the hot spot was estimated to encompass approximately 38 acres, located at variable depths between 220 to 500 feet below ground surface (bgs), and to contain 3,400 pounds of VOCs (Appendix A). Closely associated with this hot spot was a fringe zone of VOC-containing groundwater at 500 to 1,000 µg/L that encompasses an additional 29 acres and 2,500 pounds of VOCs.

The OU2 ROD stated that the goal of the remediation system is:

> "mass contaminant removal through groundwater extraction and treatment in an offsite area near the GM 38 monitoring well cluster;"

In addition, the ROD stated:

> "The GM-38 Area remedial system is being designed to intercept the majority of the contamination in this area, such that at the end of operation, the quality of the remaining

groundwater in the area will be similar to or less than the remainder of the offsite plume. By meeting this objective, potential impacts to down gradient water receptors will be minimized."

The purpose of this report is to present and evaluate: the results of a hydraulic capture zone evaluation conducted in 2013 for GM-38 recovery wells RW01 and RW03 and Bethpage Water District (BWD) Wells 4-1 and 4-2; groundwater and recovery well analytical data through June 2013; and develop a path forward for GM-38 GWTP, including any actions that may be required to enhance or reduce the system in response to evolution of the target aquifer as the groundwater in the hot spot is captured. The BWD Wells 4-1 and 4-2 are considered in this report because of the close proximity between the BWD wells and the GM-38 recovery wells, which would effect the hydraulic evaluations. Data used in this evaluation are from a compilation of reports and includes area groundwater and water data from 1999 through June 2013. These data are presented in Appendix B (Table B-1). In particular, data for February 2010 and June 2013 are used in this evaluation. February 2010 represents the date near the startup of the GM-38 GWTP and the time at which regular sampling data is available. The June 2013 data is from an area-wide investigation, with data available for most of the monitoring wells, including those in the GM-38 Area.

1.2 REPORT ORGANIZATION

The report consists of five sections. Section 1.0 provides an introduction. Section 2.0 provides site background including the review of the requirements in the 2003 ROD. Section 3.0 summarizes the field activities associated with the GM-38 Area pumping tests, including BWD Plant 4. Section 4.0 presents and evaluates data from the pumping test activities, capture zone analysis, and analytical data from the GM-38 GWTP operation and groundwater monitoring program. Section 5.0 presents the conclusions and recommendations from the evaluations.

2.0 SITE BACKGROUND

2.1 SITE LOCATION

The former NWIRP Bethpage facility is located in east central Nassau County on Long Island, approximately 30 miles east of New York City (Figures 1-1 and 1-2). In the early 1990s, the NWIRP property totaled approximately 109.5 acres and was formerly a Government Owned, Contractor-Operated facility that was operated by Northrop Grumman (NG) until September 1998. NWIRP Bethpage was bordered on the north, west, and south by property owned, or formerly owned, by NG that covered approximately 500 acres, and on the east, partially by NG facilities and largely by a residential neighborhood.

The GM-38 Area (Figure 1-3) initially referred to a cluster of monitoring wells that were installed in the early 1990s by NG that first identified an isolated groundwater VOC plume in this area. A defined source of these VOCs was not identified, but was believed to be at least partially associated with the NWIRP because of the location and type of chemicals identified. The GM-38 Area is approximately 8,500 feet south southeast and in the general hydraulically downgradient direction from NWIRP Bethpage. The GWTP is located within a utility easement that is located east of Broadway Avenue, west of the Seaford Oyster Bay Expressway (Route 135), and between the north and south dead ends of Wundhorst and Herman Avenues (Figure 1-3). The treatment plant is located on property owned by the Town of Oyster Bay and leased to the Navy.

2.2 GEOLOGY

Bethpage, New York is underlain by approximately 1,100 feet of unconsolidated sediments that overlie crystalline bedrock. The unconsolidated sediments consist of four distinct geologic units that in descending order are the Upper Glacial Formation, the Magothy Formation, the Raritan Clay Member of the Raritan Formation, and the Lloyd Sand Member of the Raritan Formation. The crystalline bedrock consists primarily of metamorphic and igneous rocks including schist, gneiss, and granite. The regional dip of the bedrock is to the south-southeast. All of the geologic units dip in this direction, although to varying degrees (Isbister, 1966).

The Upper Glacial Formation (commonly referred to as glacial deposits) forms the surface deposits in the Bethpage, New York area. These glacial deposits consist chiefly of coarse sands and gravels. The deposits are generally about 30 to 45 feet deep, but local variations in thickness are common due to irregular and undulating contact with underlying Magothy Formation.

2.3 HYDROGEOLOGY

The Upper Glacial and Magothy Formations comprise the aquifer of concern in the Bethpage, New York area. Regionally, these formations are regarded as forming a common, interconnected aquifer as the coarse nature of each unit near their contact and the lack of any regionally confining clay unit allows for the unrestricted flow of groundwater between the formations.

The Upper Glacial aquifer is no longer considered an important source of potable water in the Bethpage, New York area. It is now pumped only for a minor industrial use. In other parts of Long Island, however, this aquifer is still a major source of potable water. The Upper Glacial aquifer is generally a high yielding unit with favorable hydraulic characteristics. The glacial deposits are characterized by a moderate to high primary porosity and permeability.

The Magothy Formation is the major source of public water in Nassau County. The most productive water-bearing zones are the lenses of sand and gravel that occur within the generally siltier matrix. A major water-bearing zone is the basal gravel. Results of pumping tests conducted on NWIRP Bethpage indicate that the horizontal hydraulic conductivity of the Magothy Formation beneath the NWIRP is about 100 feet/day and the vertical hydraulic conductivity ranged from a high of 10.27 feet/day to a low of 3.98 feet/day (HNUS, 1994). Because of the extreme lateral and vertical lithologic heterogeneity of the Magothy, any hydraulic values obtained will be strongly dependent on both the geographic location of the test and the stratigraphic (vertical) section covered by the test.

2.4 GM-38 AREA BACKGROUND

2.4.1 Nature and Extent of the GM-38 Area Groundwater

Pre-GWTP Startup Characterization: The GM-38 Area was identified in the early 1990s when NG installed and sampled monitoring wells GM-38D and -38D2. Total VOC (TVOC) concentrations in the mid- to late 1990s ranged from approximately 120 µg/L to approximately 1,400 µg/L. Data from these wells in the late 1990s and early 2000s are presented in Table 2-1 (Arcadis Geraghty and Miller [Arcadis] 2000, 2001, and 2002).

Table 2-1 - GM-38D and -38D2 VOC Concentrations In 1999 to 2001

Parameter	GM-38D (µg/L)			GM-38D2 (µg/L)		
Well Screen Depth (feet bgs)	320 to 340			475 to 495		
Sample Date	Jun 1999	Sep 2000	Sep 2001	Sep 1999	Sep 2000	Sep 2001
Trichloroethene	1,000	720	810	622	1,300	1,500
Tetrachloroethene	ND	2	2	ND	ND	2
cis-1,2-Dichloroethene	ND	2	ND	6	12	9
Vinyl Chloride	ND	ND	ND	ND	ND	ND
Total VOCs	1,000	724	812	628	1,312	1,511

ND – not detected.

Between 2000 and 2002, seven borings were installed side- and down-gradient of this area to determine the horizontal and vertical extent of the GM-38 Area Groundwater (VPB-38, -40, -42, -47, -48, -51, and -77), (Figure 1-2). At that time, the upgradient extent of the GM-38 Area Groundwater was thought to have been delineated based on existing monitoring wells. Elevated concentrations of chlorinated VOCs, at concentrations of approximately 1,000 µg/L or greater, were identified in groundwater samples in three of these borings (VPB-38, -47, and -51). The boundaries of the GM-38 Area Groundwater were then estimated based on interpolation and extrapolation of this data. The depth and thickness of the GM-38 Area Groundwater varied throughout the area from approximately 220 to 260 feet bgs in the northeastern section, 250 to 500 feet bgs in the western section, and 340 to 400 feet bgs in the southern section. The maximum TVOC concentration detected was 3,400 µg/L.

Chlorinated VOCs other than trichloroethene (TCE) were detected in the groundwater samples, but generally at concentrations less than 10 percent of the total VOC concentration. There were some notable exceptions to this characterization. For example, a groundwater sample collected at VPB-51 at 240 feet bgs contained tetrachloroethene (PCE) at a maximum concentration of 900 µg/L (29 percent of TVOCs), cis-1,2-dichloroethene (1,2-DCE) at a maximum concentration of 1,100 µg/L (35 percent of TVOCs), and vinyl chloride at a maximum concentration of 300 µg/L (9.6 percent of TVOCs). PCE is a solvent that was used at NWIRP Bethpage and NG Bethpage facilities, but is also commonly used by other facilities such as dry cleaners. Complicating this evaluation, TCE is a biodegradation product of PCE, and 1,2-DCE and vinyl chloride are biodegradation products of TCE. In addition, each of these VOCs were later identified to also be associated with the former Grumman Settling Ponds Site (OU-3). As a result, although the source of these impacts could not be determined, it was originally considered to be part of the GM-38 Area Groundwater.

In 2003, the GM-38 Area Groundwater Remedy Analysis Report (2003 Report) was prepared to develop the groundwater extraction system and a conceptual design for the GWTP (Tetra Tech, 2003). To address potential uncertainty in the areal extent of the GM-38 Area Groundwater, two areas were identified for the 1,000 µg/L isoconcentration contour and two areas were identified for the 500 µg/L

isoconcentration contour. Figure 2-1 from the Remedy Analysis Report is presented in Appendix A and illustrates these four areas. One set of isoconcentration contours was based on the maximum concentration of TVOCs detected in each boring (outer contours) and the other set of isoconcentration contours was based on the average TVOC concentration within certain vertical boundaries used by the NG groundwater computer model layer (typically 100 to 200 feet thick). For this report, the GM-38 Area Groundwater is defined based on the maximum TVOC concentration in each boring using the 1,000 µg/L isoconcentration contour. As indicated in Appendix A, the areal extent of the maximum TVOC 1,000 µg/L contour is similar to the areal extent of the average TVOC 500 µg/L contour. Basic properties of this plume using the maximum TVOCs are summarized in Table 2-2.

Table 2-2 – Properties of the GM-38 Plume

Parameter	Greater than 500 µg/L of TVOCs Contour	Greater than 1,000 µg/L of TVOCs Contour
Areal Extent (acre)	67	38
Volume of Groundwater within the contour (million gallon)	446	185
2003 Estimated mass of TVOCs (pound)	5,800	3,200

Post-GWTP Startup Characterization: Since the GM-38 GWTP recovery wells blend groundwater from the various horizontal and vertical portions of the GM-38 Area, the average characteristics of the GM-38 Area Groundwater quality can be determined using analytical data from the recovery wells. A comparison of the 2010 and 2013 data with estimates from 2003 Report on the anticipated post-GWTP startup data would reveal any significant anomalies between the three data sets.

For GM-38 Recovery Well RW01 (RW01), based on the 2003 Report evaluation, the TVOC concentration in this recovery well should be 566 µg/L versus an actual TVOC concentration in February 2010 of 1,081 µg/L (Table 2-3). Similarly for GM-38 Recovery Well RW03 (RW03), based on the 2003 Report VPB data, the TVOC concentration in this recovery well should be 284 µg/L versus an actual TVOC concentration in February 2010 of 660 µg/L. Based on this comparison, in 2010, the GM-38 GWTP was initially extracting approximately twice as much TVOC mass as was originally anticipated. By June 2013, 6,450 pounds of TVOCs had been extracted and treated, and significantly exceeded the 2003 Report estimates of 3,200 pounds of TVOCs for the 1,000 µg/L isoconcentration contour, and to a lesser extent the 5,800 pounds of TVOCs for the 500 µg/L isoconcentration contour (Appendix A).

To evaluate the types of TVOCs extracted, the relative percentage of individual VOCs can be used (Table 2-3). For RW03, the percentage of TCE to TVOC anticipated in 2003 versus the actual TCE to TVOC extracted in 2010 was approximately the same (97.5 versus 98 percent). However, significant differences were noted for RW01. In particular, the percentage of PCE, 1,2-DCE, and vinyl chloride are

approximately twice as high in 2010 as was originally anticipated 2003. It is uncertain as to whether the higher concentrations of these VOCs are related to the capture of relatively shallow VOCs detected in VPB-51 or some other unidentified plume.

2.4.2 Water Quality of Groundwater Outside the GM-38 Area Groundwater

To determine the quality of groundwater outside of the GM-38 Area Groundwater, data from nearby public water supply wells, the Bethpage Community Park (BCP) OU3 groundwater plume, and other nearby groundwater monitoring wells were considered.

Public Water Supply Wells: Three public water supply systems (BWD Plants 4, 5, and 6), with a total of five wells, operate in the vicinity of the GM-38 Area (BWD 4-1, 4-2, 5-1, 6-1, and 6-2) (see Figure 1-2). BWD Plant 4 is located approximately 400 feet north of the GW-38 GWTP and at the northeastern edge of the GM-38 Area Groundwater. BWD Plant 5 is located approximately 1,200 feet south-southwest of the GM-38 GWTP, and BWD Plant 6 is located approximately 3,000 feet west of the GM-38 GWTP. Extraction depths (based on well screen interval) and VOCs detected in these public water supply wells in June 2005 are presented in Table 2-4.

Table 2-4 – Nearby Public Water Supply Data – June 2005

Parameter	BWD Well 4-1 (µg/L)	BWD Well 4-2 (µg/L)	BWD Well 5-1 (µg/L)	BWD Well 6-1 (µg/L)	BWD Well 6-2 (µg/L)
Well Screen Depth (feet bgs)	561 to 611	561 to 611	679 to 740	328 to 381	700 to 770
Trichloroethene	17	7.9	ND	130	24
Tetrachloroethene	ND	ND	ND	4.7	ND
cis-1,2-dichloroethene	3.0	0.64	ND	1.0	ND
Vinyl Chloride	ND	ND	ND	ND	ND
Total VOCs	25	9.3	ND	136	24

ND – not detected.
TVOCs include other VOCs not shown.

In 2005, the TVOC concentrations in nearby public water supply wells ranged from non-detect to 136 µg/L. Each of these public water supply wells has treatment in place that is designed to effectively treat VOCs at these concentrations.

BCP OU3 Groundwater Plume: In the late 2000's, a groundwater plume associated with the BCP OU3 was identified to be present in the general vicinity of the GM-38 Area Groundwater. Based on the conceptual site model, this plume is located deeper than (flows underneath) the GM-38 Area Groundwater. The quality of the groundwater associated with the BCP OU3 plume is presented in Table 2-5. Based on the data available from NG investigations, this plume starts near the water table at the BCP approximately 8,000 feet north of the GM-38 Area and sinks as it moves to the south. The sinking

of the plume results from both natural vertical gradients (precipitation) and the operation of relatively deep public water supply wells. By the time the BCP OU3 plume reaches the GM-38 Area, it is understood to be present at a depth greater than 550 feet, or below the maximum depth of the GM-38 Area Groundwater. As it approaches the GM-38 Area Groundwater, the core of the BCP OU3 groundwater can be characterized by the relatively high concentration of TVOCs (greater than 2,000 µg/L) and the relatively high percentage of 1,2-DCE (12.3 to 31.7 percent).

Groundwater Vertical Profile Borings and Monitoring Well Results: The maximum concentrations of VOCs in monitoring well and vertical profile boring groundwater samples adjacent to the GM-38 Area Groundwater are summarized in Table 2-6 (Appendix B, Tetra Tech 2000 and 2002, and Arcadis 2009).

Table 2-6 – VOC Concentrations In Regions Near the GM-38 Area Groundwater[1]

Parameter	BWD Well 4-1	VPB-48	VPB-77	VPB-40	RW3-MW2	VPB-116
Sample Date	Jun 2013	May 2001	Jun 2000	Aug 2001	Jun 2013	Mar 2008
Well Screen Depth (feet bgs)	561 to 611	262 to 263	256 to 257	283 to 284	330 to 350	240 to 500 (average)[2]
Distance from GM-38 Area (feet)/Orientation	<100 North	700 West	1,200 Southeast	800 Southwest	400 West	400 North
Trichloroethene	93.6	88	25	320	140	21
Tetrachloroethene	ND	6	100	3	ND	91
cis-1,2-Dichloroethene	17.6	ND	ND	ND	ND	23
Vinyl Chloride	ND	ND	ND	ND	ND	3
Total VOCs	120	102	125	327	140	138

ND – not detected.
Total VOCs include constituents not identified in the table.
[1] Except for VPB-116, the results shown represent the maximum concentration VOC concentrations in the vertical profile borings (VPBs).
[2] TVOC concentrations in VPB-116 at 575 feet bgs total 2,040 µg/L. VPB-116 is co-located with MW-116-5.

Although this table does not present a full range of water quality in the OU2 and OU3 groundwaters, it represents an approximate upper limit of VOC concentrations in the nearby groundwater that is not part of the GM-38 Area Groundwater and includes groundwater that is west, south, and east of GM-38 GWTP that will not be captured by it. Except for VPB-40, the TVOC concentration in these locations ranged from 102 to 140 µg/L. The inclusion of VPB-40 with a concentration of 327 µg/L was specifically addressed in the OU2 ROD - response to comments. Since "relatively little mass" was present in this area, capture of this groundwater was not included identified as part of the hotspot in the ROD or the design.

2.5 GM-38 GWTP SYSTEM SUMMARY

The construction of the GM-38 GWTP began in June 2008 and was completed in June 2010. The GM-38 GWTP commenced partial operation in October 2009 with the startup of recovery well RW01, and full operation in March 2010, with continuous operation of recovery well RW03. In order to achieve hydraulic

containment of the GM-38 Area Groundwater, RW01 and RW03 were designed to extract groundwater from the aquifer at a rate of 800 gallons per minute (gpm) and 300 gpm, respectively. The GM-38 GWTP consists of the following components:

- Groundwater recovery wells (RW01 and RW03)
- Equalization Tank
- Air Stripping Tower
- Liquid Phase Granular Activated Carbon Polishing
- Discharge of Treated Groundwater to a Recharge Basin or an Injection Well
- Vapor Phase Treatment using Granulated Activated Carbon (two-stage) and Permanganate-Based Resin.

Since startup in October 2009 through June 2013, the GM-38 GWTP has treated approximately 1.7 billion gallons of water and 6,450 pounds of VOCs (Appendix A).

2.6 GM-38 GWTP MONITORING PROGRAM

The GM-38 GWTP monitoring program includes collection of monthly groundwater samples from recovery wells RW01 and RW03; quarterly water level measurements from twelve GM-38 Area monitoring wells; and quarterly groundwater samples from seven GM-38 Area monitoring wells (Figure 1-3). Monitoring Wells GM-38D and -38D2 are monitored quarterly by NG. The requirements of the groundwater sampling program are provided in the *Final Operation, Maintenance, and Monitoring Plan for Groundwater Treatment Plant, GM-38 Area Groundwater Remediation* (Tetra Tech EC, 2010). Tables 2-7 and 2-8 provide a summary of the wells included in the GM-38 GWTP monitoring program. Each of the samples are analyzed for Target Compound List (TCL) VOCs. Regular sampling of the GM-38 Area monitoring wells and recovery wells started in early 2010.

3.0 GM-38 AREA PUMPING TEST FIELD ACTIVITIES

This section provides a summary of the pumping test field program. The pumping tests were conducted in accordance with the Letter Work Plan for *Water Level and Pumping Test Activities to Support GM-38 Capture Zone Analysis, NWIRP Bethpage, New York* (Tetra Tech, 2012) and utilized GM-38 GWTP recovery wells RW01 and RW03 and BWD Plant 4 production wells (BWD 4-1 and BWD 4-2). Pre-pumping test baseline groundwater level readings were collected for the observation wells from March 24, 2013 and April 1, 2013 and then four pumping tests were conducted in the GM-38 Area between April 2, 2013 and April 13, 2013, as follows:

- Pumping Test 1-1: April 2 to 3, 2013 with RW01 operating;
- Pumping Test 1-2: April 4 to 6, 2013 with RW03 operating;
- Pumping Test 1-3: April 8 to 9, 2013 with RW01 and RW03 operating; and
- Pumping Test 1-4: April 11 to 13, 2013 with BWD 4-1 and/or BWD 4-2 operating.

Table 3-1 provides a summary of each pumping test and includes the duration of pump operation, the pumping rate, gallons pumped, and cumulative gallons pumped. During the pumping tests, recovery wells RW01 and RW03 operated at approximately 800 gpm and 200 gpm, respectively. Operation of the BWD Plant 4 production wells (BWD 4-1 and BWD 4-2) was coordinated with BWD, and when operating, the BWD Wells 4-1 and 4-2 each operated at rates of approximately 1,300 gpm (Appendix C). Properties of the four pumping wells are presented in Table 3-2.

During the pumping tests, pressure readings were collected from 18 groundwater wells using data loggers. Properties of these wells are provided in Tables 3-3. The location of each of the wells is provided in Figure 1-2.

Combined pressure transducer/data logger probes were used to collect water level data (pressure head) and temperature readings from observation wells (groundwater wells) during the pumping tests. A barometric data logger was used to collect barometric pressure data throughout the duration of the tests (baseline and pumping tests). The barometric pressure data was utilized to correct/adjust observation well pressure head data for fluctuations in atmospheric pressure. The data loggers were programmed to record data at five-minute intervals. Data was downloaded from the data loggers after the completion of each testing event (i.e., baseline water level readings and the four GM-38 Area pumping tests). During the pumping tests, manual water level readings were collected periodically from observation wells and pumping wells (GM-38 recovery wells only) to ensure the data collected by the data loggers were accurate.

4.0 PUMPING TEST AND GROUNDWATER DATA

The following section presents and evaluates data collected during the GM-38 Area Pumping Tests and the GM-38 GWTP monitoring program.

4.1 GM-38 AREA PUMPING TEST RESULTS

The results of the baseline and four individual pumping test results are discussed in this section. Well locations are presented in Figure 1-2. The output from the data loggers is detailed in Appendix D and is presented in Graphs 4-1 to 4-5, as follows:

- Graph 4-1: Water level measurements from March 20 to April 23, 2013, including the baseline period, and Pumping Tests 1-1 to 1-4;
- Graph 4-2: Pumping Test 1-1;
- Graph 4-3: Pumping Test 1-2;
- Graph 4-4: Pumping Test 1-3; and
- Graph 4-5: Pumping Test 1-4.

For each of the graphs, the pumping test is highlighted with a grey shading. The period before the first pumping test represents a baseline reading, and the time between the pumping tests represent intervals in which the aquifer was allowed to re-stabilize to non-pumping conditions. The download from the pressure transducers and barometric data loggers collected is presented in electronic form in Appendix D. As indicated on the graphs, even though the operation of the GM-38 recovery wells and BWD Plant 4 wells were controlled during the tests, one or more public water supply wells in the area remained in operation and the effects of this operation were apparent during the testing.

In reviewing the data, a variation of the water level in individual wells in response to pumping represents a hydraulic connection between the monitoring well and the pumping. However, a response does not necessarily provide a direct indication of capture. For example, groundwater from a hydraulically up gradient monitoring well can flow into the pumping well, even if little or no response is observed. Conversely, for monitoring wells located side- and down-gradient, a response in the well may be observed; however, the drawdown must be sufficient to overcome the natural groundwater gradient through the area.

If sufficient wells are present, a capture zone can be determined directly by plotting a potentiometric surface map. If sufficient wells are not present, groundwater modeling using hydraulic gradient, pumping rates, and interpolation/ extrapolation of monitoring well water level data must be used (Section 4.2).

Baseline Groundwater Level Measurements

For a period of approximately two weeks prior to the start of Pumping Test 1-1 (March 20 to April 2, 2013), water levels in 18 wells in the area were monitored (Graph 4-1). During the baseline period, GM-38 GWTP recovery wells and local water districts operated under normal winter operation practices. Starting on March 29, 2013, the GW-38 GWTP and BWD Plant 4 wells did not operate, except as indicated in the individual pumping tests. Monitoring wells N-9929 and N-10814 are water table wells that were selected to represent area-wide variations in the groundwater aquifer. The rest of the monitoring wells are screened at depths similar to the pumping wells in the area.

During this baseline monitoring period, water levels in many of the monitoring wells were noted to vary in response to the operation of another pumping well in the area, with variations in most of the wells ranging by approximately 0.5 to 1.0 foot. However, the water level in MW-118-5 varied by approximately 3 feet and the water level in MW-117-5 varied by over 4 feet. Both of these monitoring wells are screened at a depth of approximately 700 feet bgs, which is similar to the screened depths for BWD Wells 5-1 and 6-2. This magnitude of response to pumping in combination with the distance to the well provides some evidence that a substantial confining unit throughout this area may be present between 550 and 700 feet bgs. Based on a second pumping test using BWD Well 6-2 conducted in October 2013 (currently unpublished) and distinctive effects that its operation has on the water levels in MW-117-5 and -118-5, the operating well during the April 2013 pumping was likely BWD 5-1.

Pumping Test 1-1 (RW01 Operating)

During Pumping Test 1-1, RW01 was operating at 800 gpm, while RW03, BWD Wells 4-1 and 4-2 were not running (Graph 4-2). As indicated by an inflection point in water levels at the start and end of the pumping test, a response was noted in each of the GM-38 Areas monitoring wells. The most significant response occurred in RW01-MW01 and GM-38D, with an approximate 1.5-foot water level variation. RW01-MW01 is located approximately 150 feet west-northwest of RW01 and GM-38D is located 850 feet to the west northwest of RW01. Both wells are screened at the similar depths as RW01. The other GM-38 monitoring wells evaluated (GM-38D2, GM38-RW02, and GM38-RW02-MW02) were located below the RW01 screened interval and the water levels varied by approximately 0.5 foot or less. As noted during the baseline evaluation, the water levels in MW-117-5 and 118-5 experienced significant variations, but not in apparent response to the operation of RW01. In addition, the other monitoring wells in the study area (e.g., GM-71D2, -36D, -36D2, and BPOW 1-4, 1-5, and 1-6) did not exhibit an apparent response to the operation of RW01. These wells are located more than 2,000 feet from RW01.

Pumping Test 1-2 (RW03 Operating)

During Pumping Test 1-2, RW03 was operating at 200 gpm, while RW01, BWD Wells 4-1 and 4-2 were not running (Graph 4-3). As indicated by an inflection point in water levels at the start and end of the pumping test, a response was noted in each of the GM-38 monitoring wells. The most significant response occurred in GM-38D2, which is located in close proximity recovery well RW03. The water level in this well varied by approximately 1.5 feet. Water levels in the other GM-38 monitoring wells varied by approximately 0.25 to 0.5 foot. As noted during Pumping Test 1-1, the water levels in MW-117-5 and 118-5 experienced significant variations, but not in apparent response to the operation of RW03; and the other study area monitoring wells did not exhibit apparent response to the operation of RW03.

Pumping Test 1-3 (RW01 and RW03 Operating)

During Pumping Test 1-3, RW01 was operating at 800 gpm and RW03 was operating at 200 gpm, while BWD Wells 4-1 and 4-2 were off (Graph 4-4). During this pumping test, as indicated by an inflection point in water levels at the start and end of the pumping test, a response was noted in each of the GM-38 Area monitoring wells. The responses observed during Pumping Test 1-3 were similar to a combination of the responses observed during Pumping Tests 1-1 and 1-2, with drawdowns for each of the wells approaching 1.5 to 2.0 feet. In general, operating RW03, along with RW01, led to a stronger response in deeper wells, such as GM-38D2 and RW-02, than with RW01 alone.

As noted during Pumping Tests 1-1 and 1-2, the water levels in MW-117-5 and 118-5 experienced significant variations, but not in apparent response to the operation of RW01 and RW03; and the other study area monitoring wells did not exhibit apparent response to the operation of RW01 and RW03. During the operation of the GWTP, high water levels in the equalization tank resulted in short term shut downs of RW03. These shutdowns can be observed by the regular spikes in several monitoring wells (e.g., GM-38-RW02).

Pumping Test 1-4 (BWD Well 4-1 and/or 4-2 Operating)

During Pumping Test 1-4, BWD Well 4-1 and/or 4-2 were operating at approximately 1,300 gpm each, while RW01 and RW03 were off (Graph 4-5). During this pumping test, as indicated by an inflection point in water levels at the start and end of the pumping test, except for the two reference wells (N-10814 and N-9929), a response was noted in each of the study area monitoring wells. In addition, likely because of the higher pumping rates during this test, the water level responses ranged from approximately 2 to 3 feet in each of the GM-38 Area monitoring wells and 0.5 feet in the BPOW 1-4 to 1-6 monitoring wells, as well as, up gradient monitoring wells GM-71D2, MW-116-5, MW-117-5, and MW-118-5. Responses were

noted in BPOW 1-4, 1-5, and 1-6, but these responses likely resulted from the coincidental operations at South Farmingdale Water District (SFWD) Plant 1. As during the pumping tests, water levels in MW-117-5 and 118-5 also experienced significant variations, but not in apparent response to the operation of BWD Well 4-1 or 4-2.

4.2 GM-38 GWTP CAPTURE ZONE ANALYSIS

Data collected from the GM-38 Area pumping tests were utilized in an evaluation to determine the capture zone extents of GM-38 GWTP recovery wells RW01 and RW03, and more specifically whether GM-38 Area Groundwater was being captured. Calculations used to determine the horizontal and vertical capture zones of the GM-38 GWTP recovery wells are provided in the *Technical Memorandum, Evaluation of Capture of Contaminated Groundwater, Bethpage, New York (Tetra Tech, 2013)* (Appendix E) and the results are summarized below.

Figure 4-1 depicts the GM-38 Area Groundwater relative to the horizontal capture zone of each recovery well and the combined capture zone under the scenario during which both recovery wells were operating. As indicated in Figure 4-1, the RW01 capture zone encompasses most of the GM-38 Area Groundwater, but the RW03 capture zone encompasses only the northwest section of this area. In combination, the capture zone encompasses approximately 90 percent of the estimated areal extent of the GM-38 Area Groundwater. The southwestern edge of the capture zone (at the extremities of the southwestern - 10 percent portion of the GM-38 Area Groundwater) is unclear because of limited monitoring density detail at certain depths in that region, but in general, the extraction system appears to have targeted the desired horizontal area of the aquifer.

Vertical capture was determined evaluating the vertical extent of the GM-38 Area Groundwater, the local presence of confining units, the response in surrounding monitoring wells, the screened interval of the GM-38 recovery wells. Groundwater within the vertical extent of the well screens would be preferentially captured by the recovery wells. This approach was supported by the pumping test results that indicated good connection between the recovery wells and the monitoring wells screened within that depth interval. When only RW01 was pumped, a relatively strong response (0.5 foot or more) was noted not only in wells screened at various depths between 300 to 550 feet bgs (namely, GM-38D, RW1-MW1, RW2-MW2, and GM-38D2). Some of these wells are at distances of 1,000 feet or more, indicating that RW01 generates a relatively wide and deep zone of influence encompassing the target GM-38 Area Groundwater and a depth interval of 300 to 550 feet bgs. Monitoring wells shallower than 300 feet bgs (GM-36D, N-10814, and N-9929) or wells located at a distance of 2,000 feet or more did not appear to be influenced by RW01 operation.

RW03 is screened from 392 to 412 and 442 to 504 feet bgs and based on its horizontal capture zone estimate, encompasses a relatively smaller width around the monitoring well cluster GM-38D/D2. Because RW03 is screened deeper than RW01, it does not appear to influence the nearby shallower well GM-38D, although its influence on the deeper GM-38D2 is strong.

In summary, the operation of recovery wells RW01 and RW03 provided good vertical capture of the GM-38 Area Groundwater. Also, there is no clear evidence in the pump test responses that the deepest monitoring wells in the region (wells screened below 550 feet bgs, namely, MW-116-5, MW-117-5, MW-118-5, BPOW 1-5, and BPOW 1-6) are being influenced by the GM-38 recovery wells. Therefore, both horizontally and vertically, the GM-38 system capture zone has extended in a focused fashion on the GM-38 hot spot that was targeted in 2003.

A second capture zone scenario was evaluated based on the simultaneous operation of RW01, RW03 and BWD Well 4-2 operating under annual average conditions, see Figure 4-2. Since the capture zone of BWD Well 4-2 is within the capture zone of RW01, the capture zones become additive. The result is that the capture zone for RW01 extends further to the south, west, and east in this operating scenario. Under this scenario, all of the GM-38 Area Groundwater is captured with more certainty by extraction wells in this area, including the extreme southwestern portion of the GM-38 Area Groundwater.

Interestingly, when RW01 and RW03 are operated simultaneously, there is an additive effect evident on their combined capture only in the deeper wells GM-38D2 (475-495 feet bgs) and RW02 (440-510 feet bgs), not in the shallower GM-38D (320-340 feet bgs). This can be attributed to the fact that RW03 is screened at a deeper depth interval than RW01.

4.3 GM-38 AREA GROUNDWATER DATA

Analytical data from the GM-38 Area Groundwater monitoring program, including results from 13 monitoring wells and the two recovery wells RW01 and RW03, are evaluated in this section. Positive detections of VOCs are provided in Appendix B, Table B-1. The data are also presented on Figures 4-3 and 4-4. In addition, several graphs were developed to provide temporal trends, as follows:

- Graph 4-6: Recovery Well RW01 with TCE, 1,2-DCE, PCE, and vinyl chloride data;
- Graph 4-7: Recovery Well RW03 with TCE, 1,2-DCE, PCE, and vinyl chloride data;
- Graph 4-8: Monitoring Well GM38D with TCE data;
- Graph 4-9: Monitoring Well GM38D2 with TCE data; and
- Graph 4-10: Monitoring Wells associated with RW01 and RW03 with TCE data.

Recovery Well RW01 and RW03 Results (Figure 4-4 and Graphs 4-6 and 4-7)

The analytical results for recovery wells RW01 and RW03 are presented in Figure 4-4 and Graphs 4-6 and 4-7. Based on a review of this data, the concentrations of individual VOCs in RW01 have decreased consistently from February 2010 to June 2013, whereas the concentrations of TCE in RW03 decreased from February 2010 to July 2010, leveled off at approximately 300 µg/L through September 2012, and then decreased to approximately 200 µg/L by June 2013. On a mass basis, in April 2010, RW01 and RW03 were removing approximately 8.5 and 1.3 pounds per day of VOCs, respectively. In June 2013, RW01 and RW03 were removing approximately 2.4 and 0.5 pounds per day, respectively. This downward trend is consistent with an overall decrease in the TVOC mass within the GM-38 Area Groundwater. In addition, since the reduction in TVOCs exceeds 75 percent (2 half-life cycles), it allows a half-life of residual VOCs to be calculated for potential future evaluation of system performance. Based on the data trend, the calculated half-life for VOC mass in the GM-38 Area Groundwater has been approximately 26 months in the past (Appendix A).

Monitoring Wells GM-38D and GM-38D2 Results (Figure 4-4 and Graphs 4-8 and 4-9)

The analytical results for monitoring wells GM-38D and -38D2 are presented in Figure 4-4 and results for TCE only are presented in Graphs 4-8 and 4-9. From July 1999 to startup of RW01 in October 2009, the TCE concentrations in GM-38D (screened from 320 to 340 feet bgs) ranged from approximately 600 to 1,200 µg/L (Graph 4-8). Starting in September 2009, the TCE concentration in this well decreased steadily to approximately 410 µg/L in March 2012, and has remained at approximately 400 µg/L through June 2013. Based on the screened depth of GM-38D and the results of the pumping test, groundwater at this depth is likely being captured by RW01 recovery well. The plateauing VOC levels in GM-38D indicate a possible continuing shallow source of VOCs unrelated to the original determination of the GM-38 Area Groundwater.

For GM-38D2 (screened from 475 to 495 feet bgs), the TCE concentrations increased from approximately 622 µg/L in July 1999 to approximately 1,500 µg/L in September 2001, then ranged from 1,200 to 1,400 µg/L through September 2006 (Graph 4-9). Right around the time RW01 and RW03 started pumping, the TCE level was between 350 to 370 µg/L in GM-38D2. By September 2010, operation of RW01 and, particularly, RW03 resulted in a decrease in TCE to 52 ppb in this deeper well and concentrations have consistently remained less than 50 µg/L through June 2013 (with TCE at 29 µg/L). This finding indicates that any hotspot-like concentrations at deeper depths in the GM-38 Area (below 450 feet bgs) have been addressed.

GM-38 Area Monitoring Wells (Figure 4-3 and Graph 4-10)

There are ten GM-38 Area Monitoring Wells (RW1-MW1, -MW2, and -MW3 [RW1 monitoring wells], RW2-MW1, -MW2, and MW3 [RW2 monitoring wells], and RW3-MW1, -MW2, –MW3, and –MW4 [RW3 monitoring wells]), plus TP-1 a well installed near the treatment plant. These wells were originally installed to initially evaluate capture zones for the recovery wells. Prior to the startup of the GM-38 GWTP, five of the wells were sampled periodically between 2005 and 2009. Since startup of the GM-38 GWTP, seven of these wells have also been sampled and analyzed on a quarterly basis. The other wells were located in close proximity (horizontally and vertically) to the seven well and groundwater quality in these wells should be similar to the seven wells.

RW1 Monitoring Wells: The RW1 monitoring wells are located in the eastern portion of the GM-38 Area Groundwater and are screened at depths of 395 to 435 feet bgs, consistent with the lower screen depth of RW1 (410 to 435 feet bgs). RW1-MW1 is located in close proximity to recovery well RW01 and is sampled on a quarterly basis. The TCE concentration in this well have ranged from 52.7 to 140 µg/L prior to the startup of RW01, peaked at a concentration of 129 µg/L in September 2011, and was present at 78 µg/L in June 2013. Similarly, the 1,2-DCE concentration in this well ranged from 78.6 to 180 µg/L prior to the startup of RW01, was present at a maximum concentration of 179 µg/L in March 2012, and decreased to 64 µg/L in June 2013. RW1-MW1 is sampled periodically and TCE concentrations in this well ranged from 158 to 200 µg/L in 2005 to 2009 and decreased to 64 µg/L in June 2013. These low concentrations (relative to the hot spot definition) and sustained trends may be indicative of back diffusion of dissolved-phase VOCs from fine-grained material in the area. The groundwater in recovery well RW01 and some of the RW1 monitoring wells contains primarily TCE, 1,2-DCE, and/or PCE at similar concentrations.

RW2 and RW3 Wells: The RW2 and RW3 monitoring wells are located in the western portion of the GM-38 Area Groundwater and are screened at approximate depths of either 320 to 350 feet bgs (shallower wells) or 470 to 510 feet bgs (deeper wells). The shallower screen depths correspond the upper screen interval of RW01 (335 to 395 feet bgs) and potentially the upper screen interval on RW03 (392 to 412 feet bgs). The deeper RW2 and RW3 monitoring well screen depths correspond to the lower screen interval of RW03 (442 to 504 feet bgs). TCE is the primary chemical in each of these wells, with periodic lower detections of other VOCs. As indicated below, the shallower wells contain higher concentrations of VOCs than the deeper wells in this area.

From January 2010 to June 2013, the shallower RW3 well groundwater (RW3-MW2 and RW3-MW3 screened from 320 to 350 feet bgs) contained TCE at concentrations ranging from 60.9 µg/L to 209 µg/L in RW3-MW2 and from 215 µg/L to 410 µg/L in RW3-MW3. There is no apparent increasing or decreasing temporal trend for these wells. Based on the location of these wells north and west of the

GM-38 Area Groundwater, the relatively steady concentrations over time provide evidence of a continuing shallow source of VOCs flowing into the GM-38 Area Groundwater. There is insufficient data in the shallow aquifer in this area to determine the extent or mass of VOCs associated with it.

The deeper RW02 and RW03 monitoring wells (RW2-MW1, -MW2, and -MW3, RW3-MW1, and RW3-MW4 screened from 475 to 510 feet bgs) had TCE results ranging from non- detect to 77.6 µg/L. There is no apparent increasing or decreasing temporal trend for these wells and the sustained relatively low concentrations are indicative of back diffusion from finer-grained layers in the area.

4.4 United States Geological Survey (USGS) Modeling Results

In 2013, USGS conducted an independent evaluation of groundwater flow in the GM-38 Area (Misut, 2014). In this study a numerical model was used to improve understanding of the effect of the GM–38 system on Hot Spot containment and the advective processes capturing Hot Spot VOCs. The Hot Spot was divided into two regions or volumes, the inner solid and the outer solid ring, and was delineated based on previous contouring efforts.

Model simulations were also conducted to improve understanding of how the following factors affect GM–38 zones of contribution (ZOCs): other nearby pumping; modeled constant head and flow boundaries; and heterogeneity in the Magothy aquifer. Both forward- and backward-particle tracking analyses were conducted and essentially yielded the same conclusion that the GM–38 GWTP is highly effective at capturing the GM–38 Hot Spot. The forward-tracking simulations focus on the fate of the GM–38 Hot Spot, while the backward-tracking simulations focus on particle movement processes that are affected by well hydraulic stress and how these processes relate to a detailed three-dimensional rendering of the Hot Spot volumetric solid. The percentage of backward-tracked particles, started at GM–38 wells that were sourced from within the Hot Spot, varied from 72.0 to 98.2, depending on the Hot Spot delineation used. The percentage of forward-tracked particles that were captured by GM–38 wells varied from 81.1 to 94.6, depending on the Hot Spot delineation used, with the remainder primarily captured by Bethpage Water District Plant 4 production wells. Less than one percent of forward-tracked particles ultimately discharge at model constant head and drain boundaries. The differences between percentage ranges are due to some forward-tracked particles not being captured by GM38 wells, and some backward-tracked particles not intersecting specific regions of the Hot Spot.

Because the model is very much a simplification of the real conditions and because values of important physical controlling parameters are to a large extent uncertain, this analysis considers variations of both parameter values and hydrologic conditions, in order to bracket important factors that control GM–38 ZOCs. By use of borehole logs, a transitional probability approach generated alternate representations of heterogeneity within the Magothy aquifer. Low hydraulic conductivity fine-grained sediments were laterally discontinuous, thickening towards the south, and found to statistically comprise about 17 percent

of the total aquifer volume realized in the area of interest surrounding the GM–38 Hot Spot. Through transitional probability analyses, the robustness of the estimates for hydraulic conductivity and, therefore ZOCs, were demonstrated.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The GM-38 GWTP has achieved its primary goal of successfully capturing the portion of the aquifer targeted as a hot spot in 2003. This achievement has been demonstrated by a combination of water level measurements, pump test results, and modeling. The conclusions developed from this evaluation are presented as follows:

1. From October 2009 to June 2013, the GM-38 GWTP has removed approximately 6,450 pounds of VOCs, which exceeded its anticipated mass removal of 3,500 to 5,500 pounds. As of June 2013, the GM-38 GWTP was removing approximately 87 pounds per month of TVOCs, primarily from RW01. The capture zone analysis shows that RW01 and RW03 exert focused capture of the GM-38 hotspot delineated in 2003 at depths between approximately 300 and 550 feet bgs in the aquifer near the GM-38 monitoring well cluster. No significant influence of the GM-38 GWTP is apparent in wells shallower than 300 feet bgs (e.g., GM-36D) or deeper than 550 feet bgs (e.g., MW-118-5) in the vicinity.

2. Recovery Well RW01, at its current flow rate of 800 gallons per minute, provided the vast majority of the mass removal for the treatment system (84.3 percent in June 2013), and its capture zone addresses all or most of the GM-38 Area Groundwater. Its capture zone is both wide and deep, as exemplified by the relatively strong response in its pump test observed in GM-38D (320-340 feet bgs) and a slightly smaller response in GM-38 D2 (475-495 feet bgs), a well cluster that is approximately 1,000 feet to the west of RW01. Recovery well RW03, at its current operating flow rate of 200 gpm, has a much smaller capture zone and its operation adds to the capture of RW01 only in deeper portions of the GM-38 Area Groundwater, influencing primarily deeper wells, such as GM-38D2 (475-495 feet bgs). When RW01 and RW03 were pumped together, there was no noticeable additive influence on the drawdown in shallower monitoring wells, indicating that in the shallower portions of the GM-38 Area Groundwater, RW01 operation is sufficient.

3. Since the operation of the GM-38 recovery wells, groundwater from monitoring wells screened in the deeper portion of the GM-38 Area Groundwater (wells screened 450 to 510 feet bgs) have declined to or shown consistently relatively low TCE levels of approximately 67 µg/L or less of TVOCs (relative to the hotspot). Therefore, any hotspot like concentrations have been addressed in the deeper portion of the GM-38 Area Groundwater and any low- levels residual VOCs are the result of back diffusion from the finer-grained units (silt and clay lenses) prevalent in the Magothy.

4. Groundwater from monitoring wells screened in the shallower portion of the GM-38 Area Groundwater (Wells screened 320 to 435 feet bgs) contain approximately 140 to 425 µg/L of

TVOCs. Concentrations of VOCs in these wells either declined or remained stable when the GM-38 recovery wells were started, and have since remained relatively constant at elevated levels. This response is indicative of the presence of a continuing source of VOCs in the nearby shallower aquifer (less than 435 feet bgs).

Recommendations for the path forward are presented as follows:

1. Since the results of the GM-38 system capture zone and groundwater analyses indicate that continued pumping of the deeper portions (greater than 450 feet bgs) of the GM-38 Area Groundwater is unlikely to generate further improvement of this part of the aquifer and VOCs will continue to diffuse slowly out of the finer-grained units at this depth, continued pumping of RW03 is unlikely to yield any additional benefit. The operation of this well can be discontinued and resources directed elsewhere.

2. There appears to be a continuing source of VOCs in the shallower portion (less than 435 feet bgs) of the GM-38 Groundwater Treatment Area that has caused VOC concentrations to level off at elevated concentrations of 147 to 410 µg/L. These levels are lower than the concentrations in the original GM-38 Area Groundwater targeted for removal, but have led to a much slower decline in VOC levels in recovery well RW01. As a result, the Navy will continue to operate RW01 for now, but will discuss its future operation with New York State Department of Environmental Conservation (NYSDEC).

3. The Navy will also discuss with NYSDEC additional investigation of the shallow aquifer (less than 550 feet bgs) to identify the continuing source of VOCs and other potentially responsible parties in the vicinity of GM-38.

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